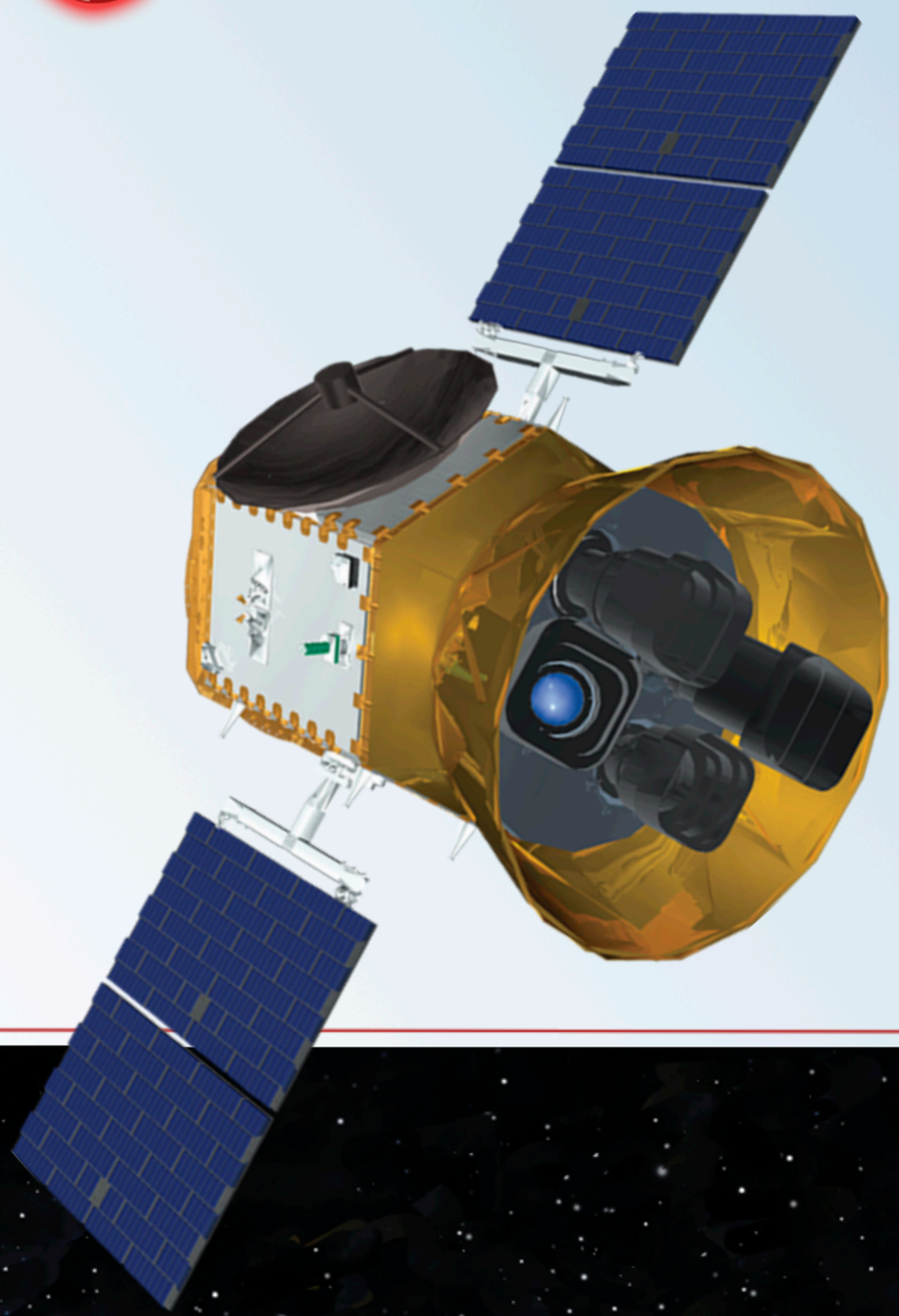
Transiting Exoplanet Survey Satellite



The TESS Mission:

Discovering New Earths and Super-Earths in the Solar Neighborhood

George Ricker (MIT)

Exoplanet Exploration Program Analysis Group Meeting #9

AAS Washington DC

5 January 2014

TESS:

The People's Telescope

…Data releases in 4 months

...2017 Launch!

MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MKI + LL)

PI, Payload, Science Center

NASA'S GODDARD SPACE FLIGHT CENTER

Mission Management, Engineering, Safety & Mission Assurance, E/PO

ORBITAL SCIENCES CORPORATION

Spacecraft Bus, Observatory I&T, Mission Operations Center

NASA AMES

Data Pipeline

SAO

Follow-Up Program, Science Center

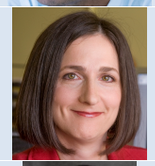
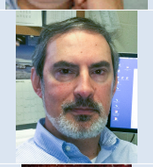
STScI

Archive, E/PO

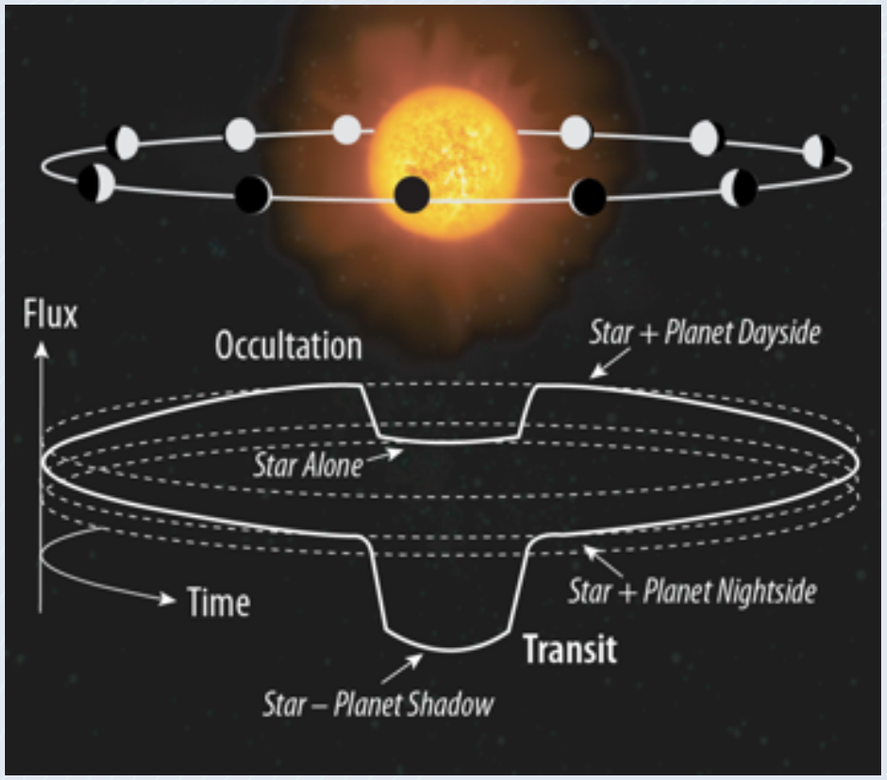
Contributors include: SAO, MPIA-Germany, Las Cumbres Observatory, Geneva Observatory, OHP-France, University of Florida, Aarhus University-Denmark, Harvard College Observatory, STScI, and Vanderbilt University. There are no mission hardware contributions.

TESS Science Team Co-I's

	G. Ricker (MIT-PI)		R. Vanderspek (MIT-DPI)

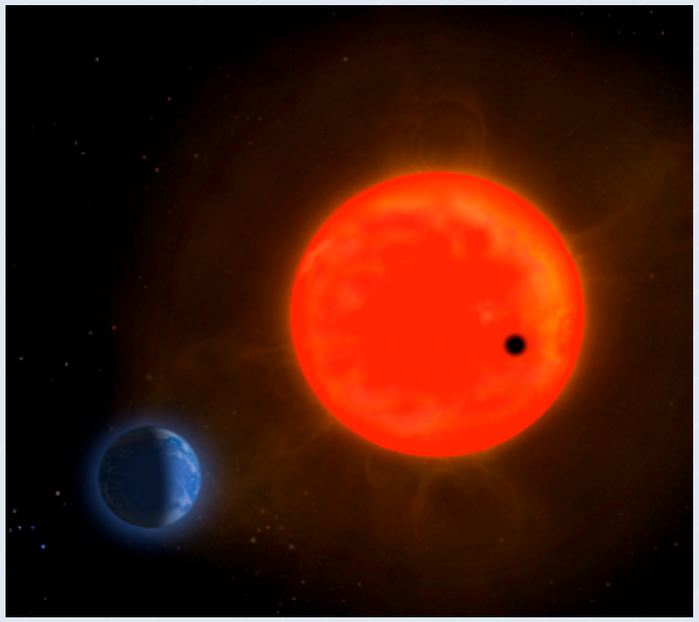
	D. Latham (CfA)		J. Doty (Noqsi/MIT)		J. Lissauer (ARC)
	J. Winn (MIT)		T. Dunham (Lowell Obs.)		P. McCullough (STScI)
	J. Villasenor (MIT)		M. Holman (CfA)		S. Rinehart (GSFC)
	G. Bakos (Princeton)		J. Jenkins (ARC/SETI)		D. Sasselov (CfA)
	T. Brown (LCOGT)		G. Jernigan (Espace/UCB)		S. Seager (MIT)
	D. Charbonneau (CfA)		L. Kaltenegger (MPIA)		K. Stassun (Vanderbilt)
	J. Christensen-Dalsgaard (DN)		G. Laughlin (UCSC)		A. Szentgyorgyi (CfA)
	M. Clampin (GSFC)		A. Levine (MIT)		G. Torres (CfA)
	D. Deming (UMd)		D. Lin (UCSC)		S. Udry (Geneva Obs.)

TESS Science Goals and Drivers



- Discover Transiting Earths and Super-Earths Orbiting Bright, Nearby Stars
  - *Rocky Planets & Water Worlds*
  - *Habitable Planets*
- Discover the "Best" ~1000 **Small** Exoplanets
  - *"Best" Means "Readily Characterizable"*
    - *Bright Host Stars*
    - *Measurable Mass & Atmospheric Properties*
  - *Present: <u>Only 2</u> small transiting exoplanets orbiting bright hosts are known*

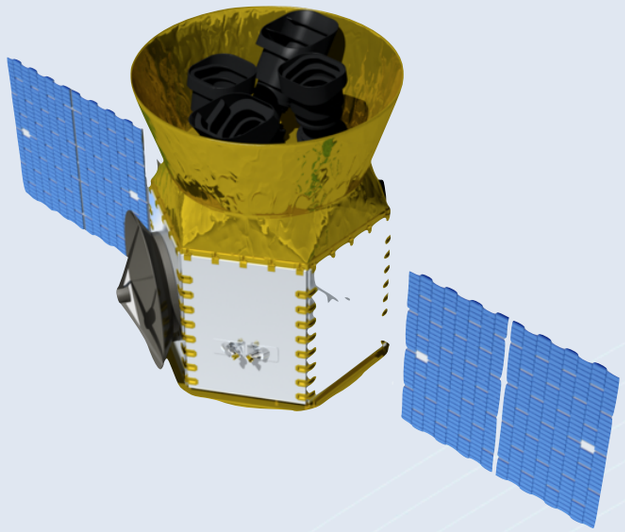
- <u>All Sky Survey</u> of Bright Stars
  - *F, G, K dwarfs: +4 to +12 magnitude*
  - *M dwarfs known within ~60 parsecs*
  - *>500,000 target stars in two years*



TESS and Kepler Address Different Questions

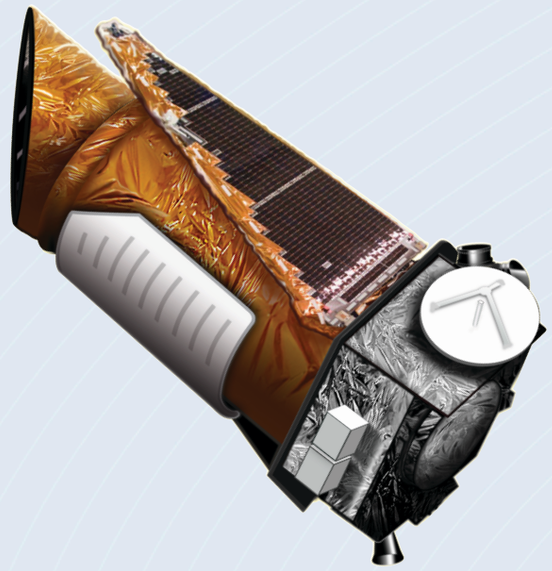
- **TESS:**

  Where are the nearest transiting rocky planets?



- **Kepler:**

  How common are true Earth analogs?

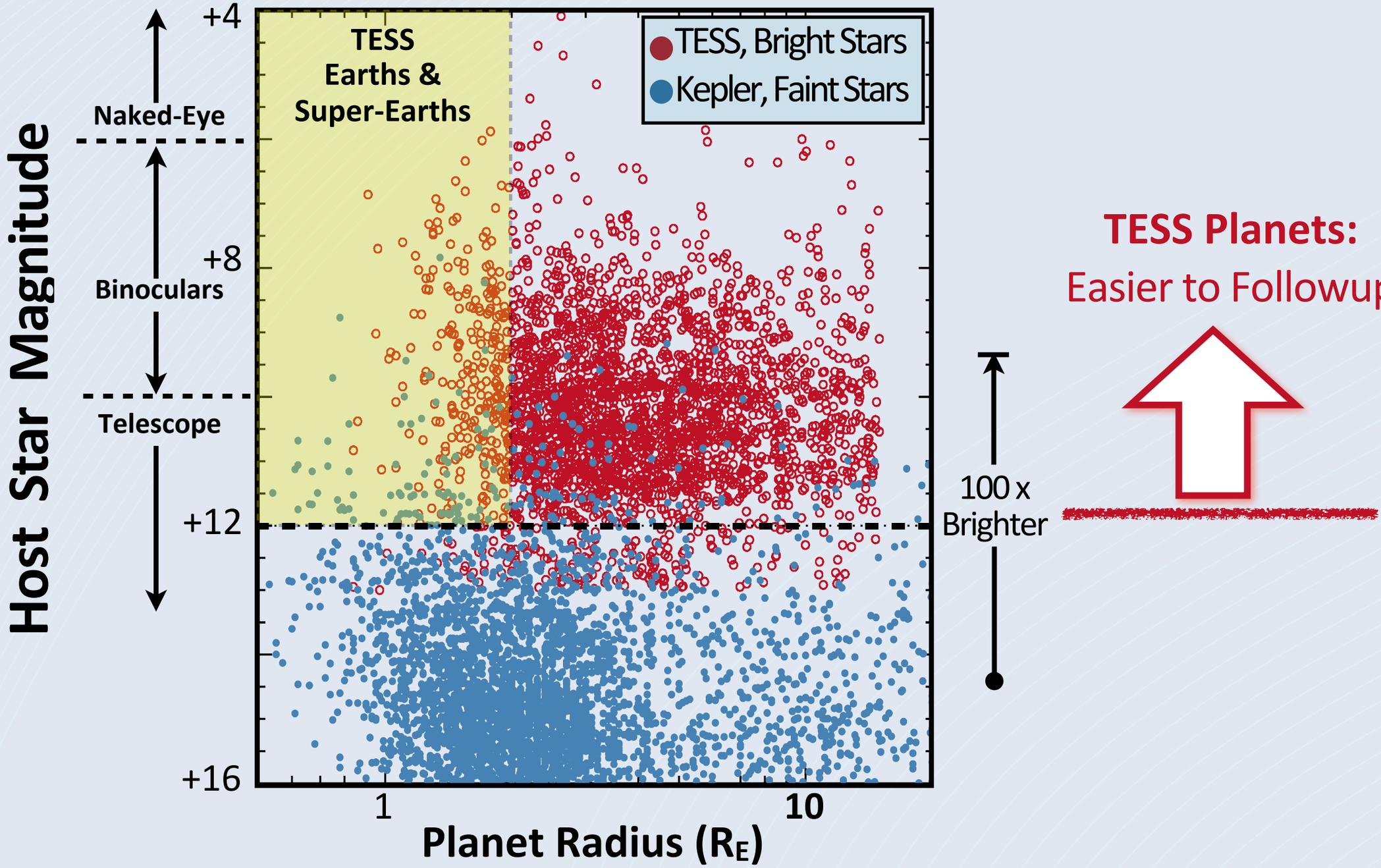


TESS Stars Are Brighter than Kepler Stars

- Why?
  - *Two reasons…both arise from TESS's focus on Solar Neighborhood*
- Solid angle coverage
  - $\Omega_{TESS} \simeq 400\ \Omega_{Kepler}$
  - *Number of accessible bright stars increased by same factor*
- Catalog star distances
  - *TESS: ~10^2 light-yr*
  - *Kepler: ~10^3 light-yr*

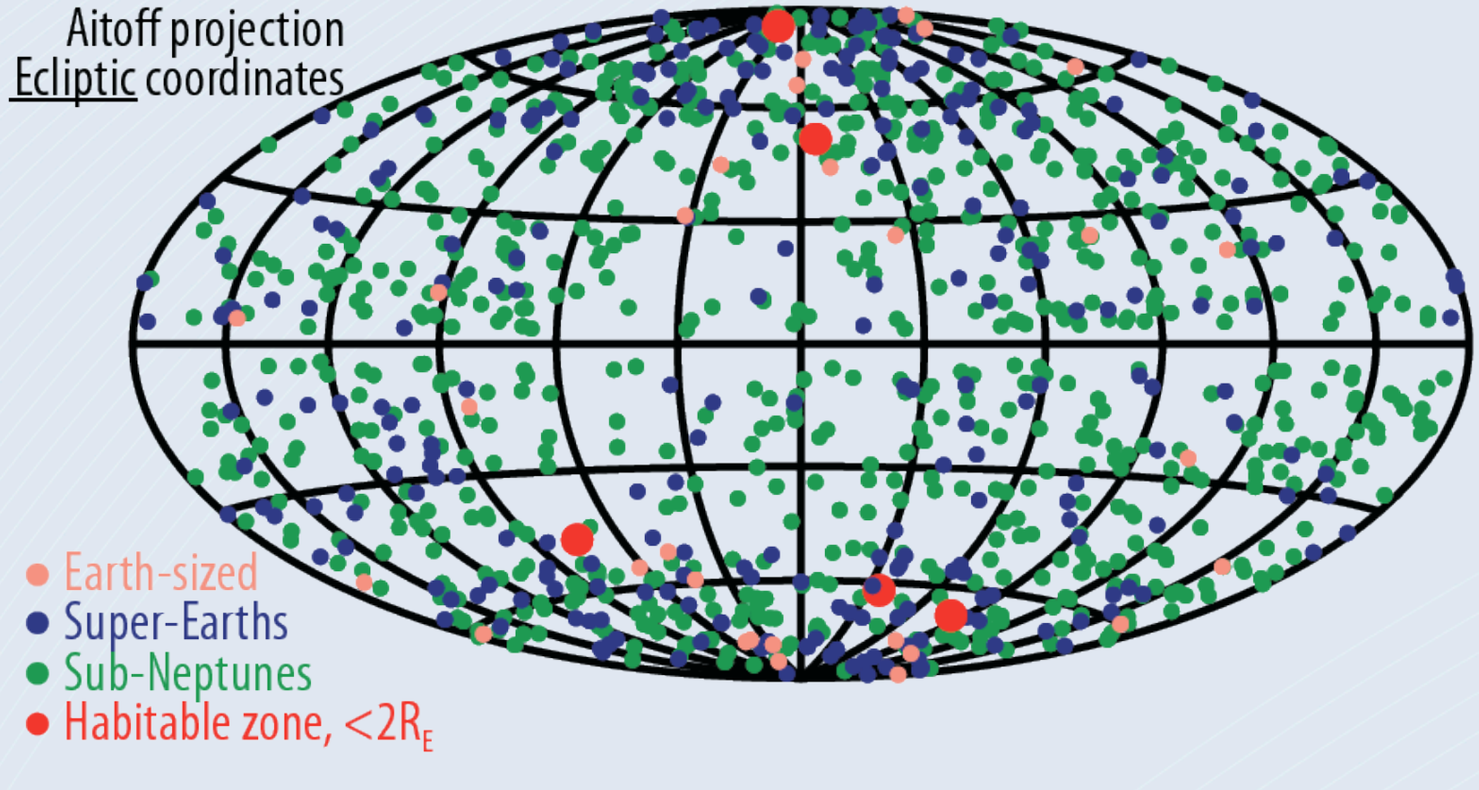
$1/R^2$ dependence means TESS stars are ~100 times brighter on average

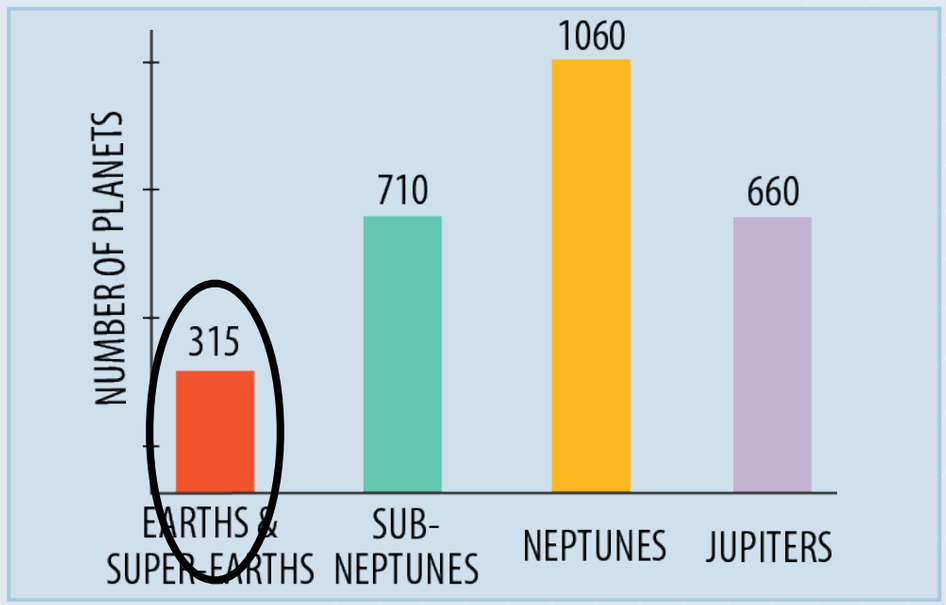
Comparison of Host Star Brightness



TESS Will Discover Earths & Super-Earths Orbiting Bright Stars

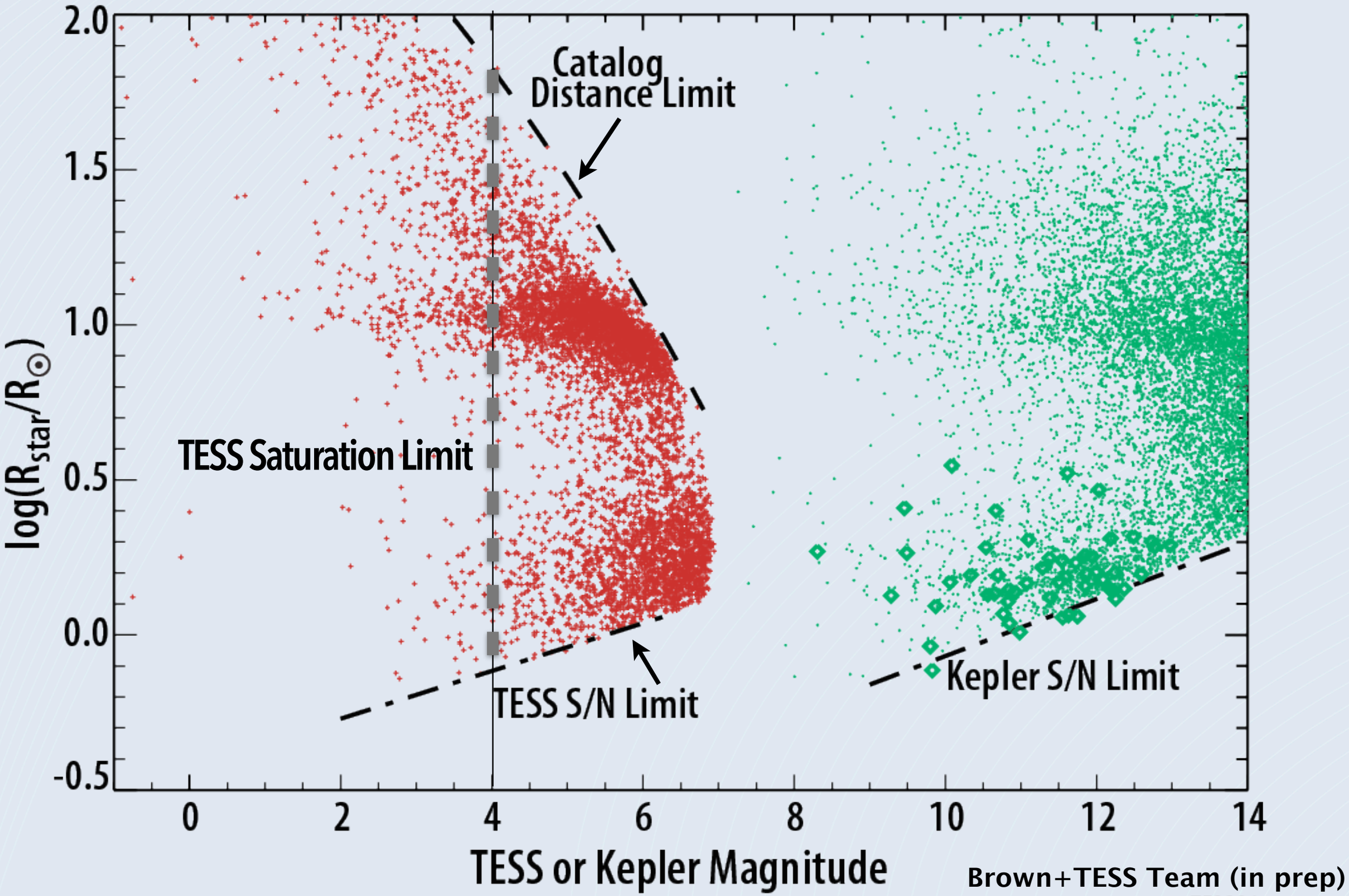
Predicted Science Yield from TESS Mission



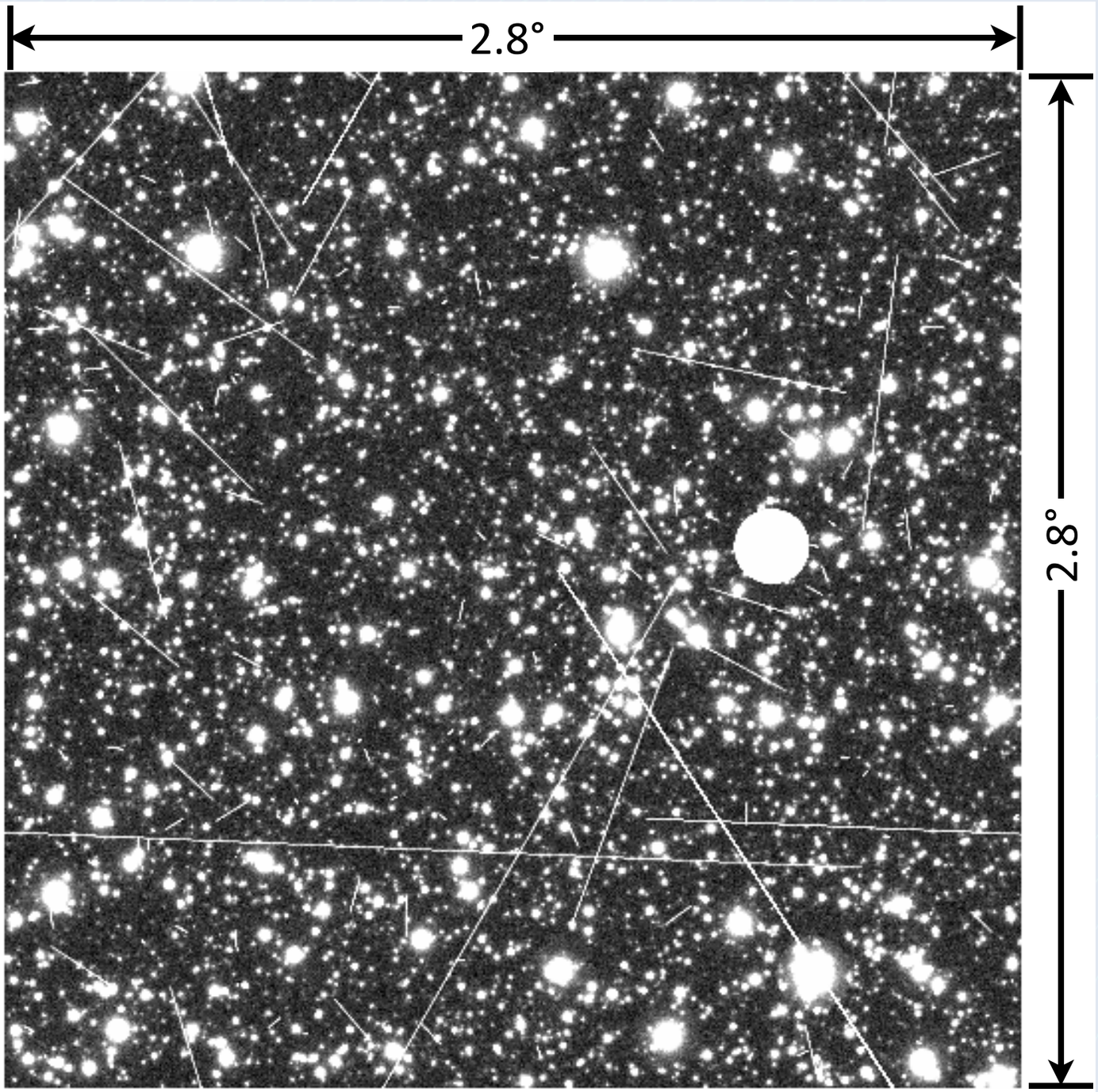


TESS Will Discover ~300 Earths & Super-Earths

Simulations: Asteroseismology with TESS



Simulated ½ Hour Stacked Full Frame TESS Image



Stack:
900 TESS images @ 2s/integration

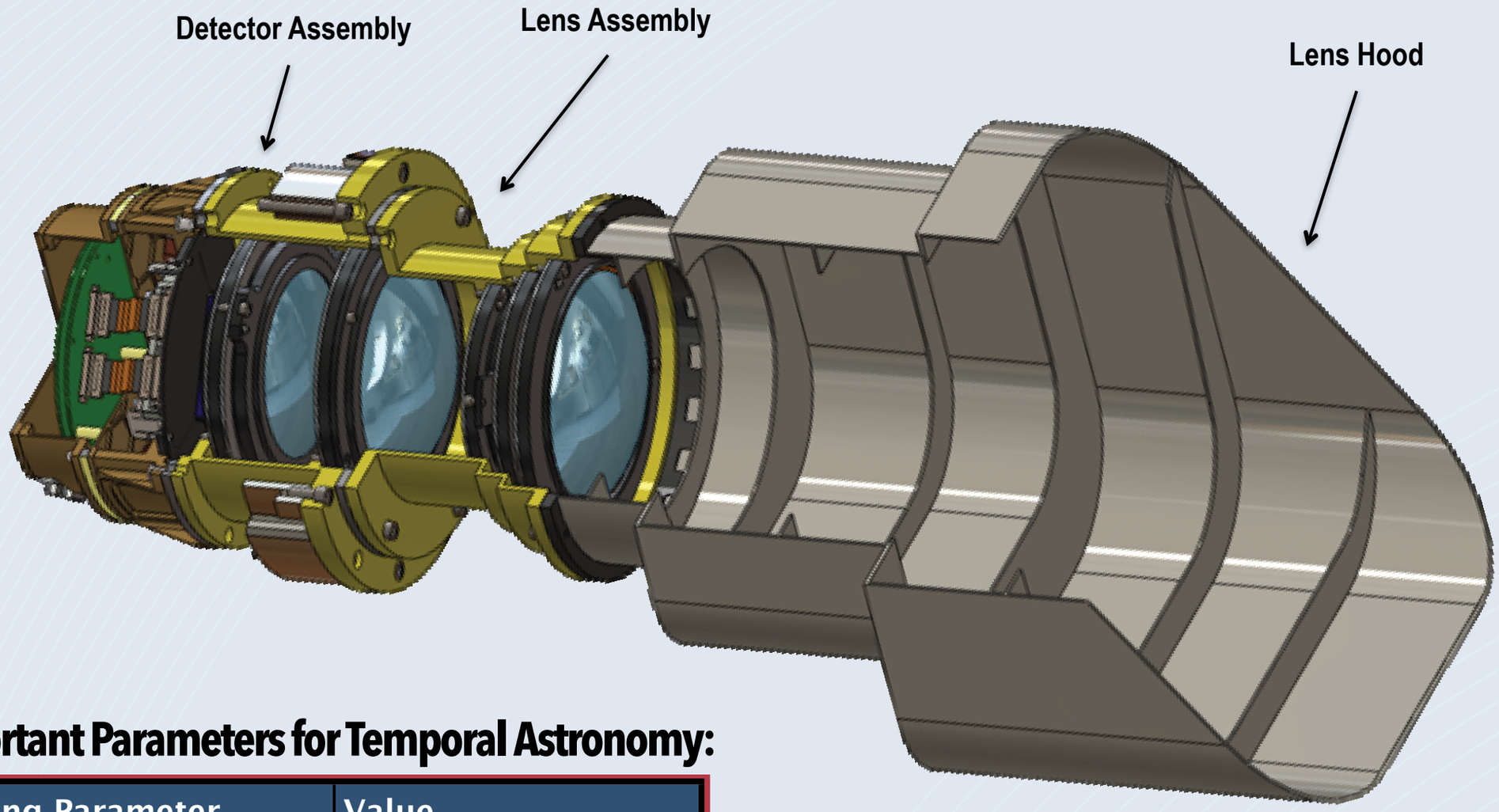
Portion of Image Stack Shown:
= 7.8 deg^2 out of 570 deg^2/camera
= 0.34% of instantaneous TESS FOV

Limiting Mag in I Band	S/N Ratio Achieved by TESS in 30 minutes	# Stars* in 40,000 deg^2
12.0	1350	≳6*10^6
13.0	600	≳12*10^6
14.0	250	≳24*10^6

*R band mean star counts from Bahcall & Soneira (1980) re-scaled to I band assuming R-I = +1.0 mag, appropriate for early M stars.

TESS Can Provide FFI's at Kepler's 30 Minute Cadence

TESS Wide FOV CCD Camera

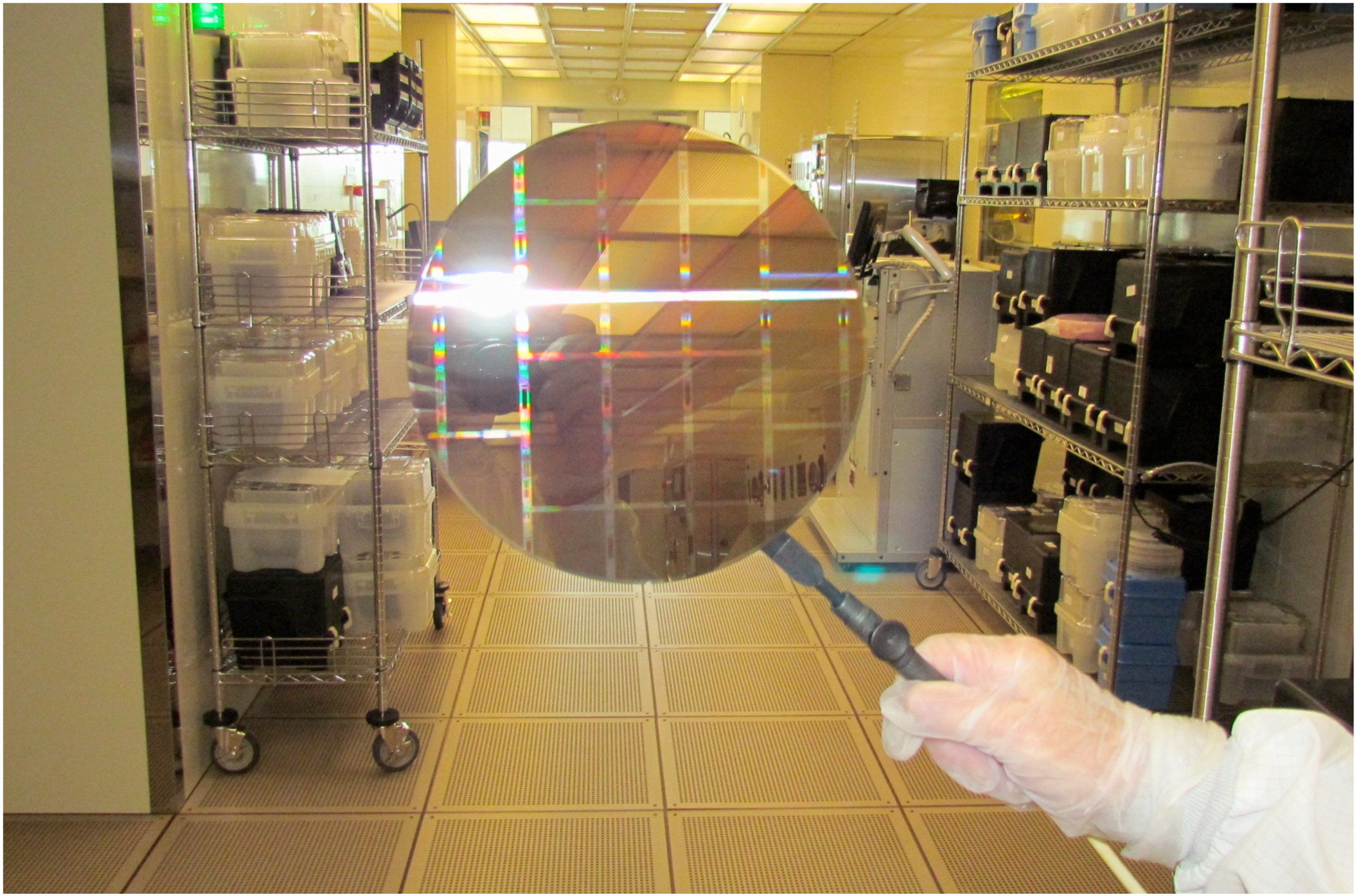


Important Parameters for Temporal Astronomy:

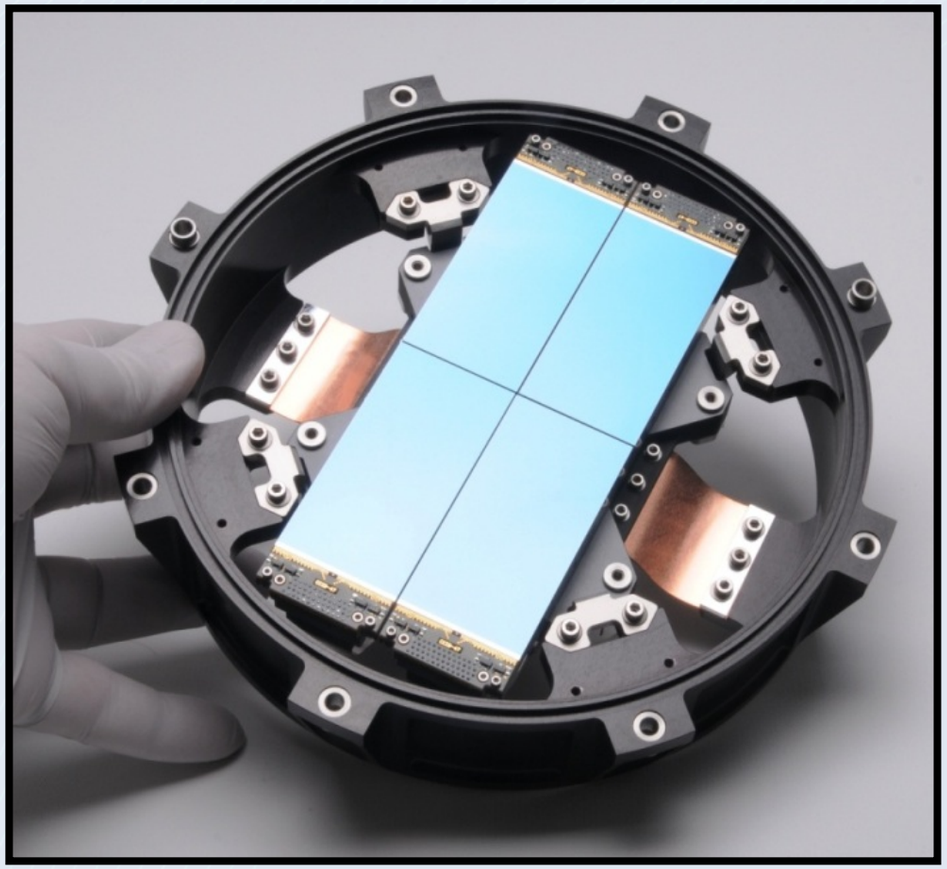
Timing Parameter	Value
Frame Time	2 sec
Transfer Time	0.004 sec
Baseline Cadence (>500,000 Stars)	1 min
Bright Star Cadence (~3,000 Stars)	30 sec (goal)
Full Frames Cadence (>20,000,000 Stars)	30 min

Optical Parameter	Value
Effective Area	60 cm^2
Passband	600—1000 nm
CCD Focal Plane Array (Frame Store Mode)	4 @ 2K x 2K pixels 15 μm/pixel
Camera FOV	24° x 24°
Number of Cameras	4 ⇒ 2304 deg^2 FOV

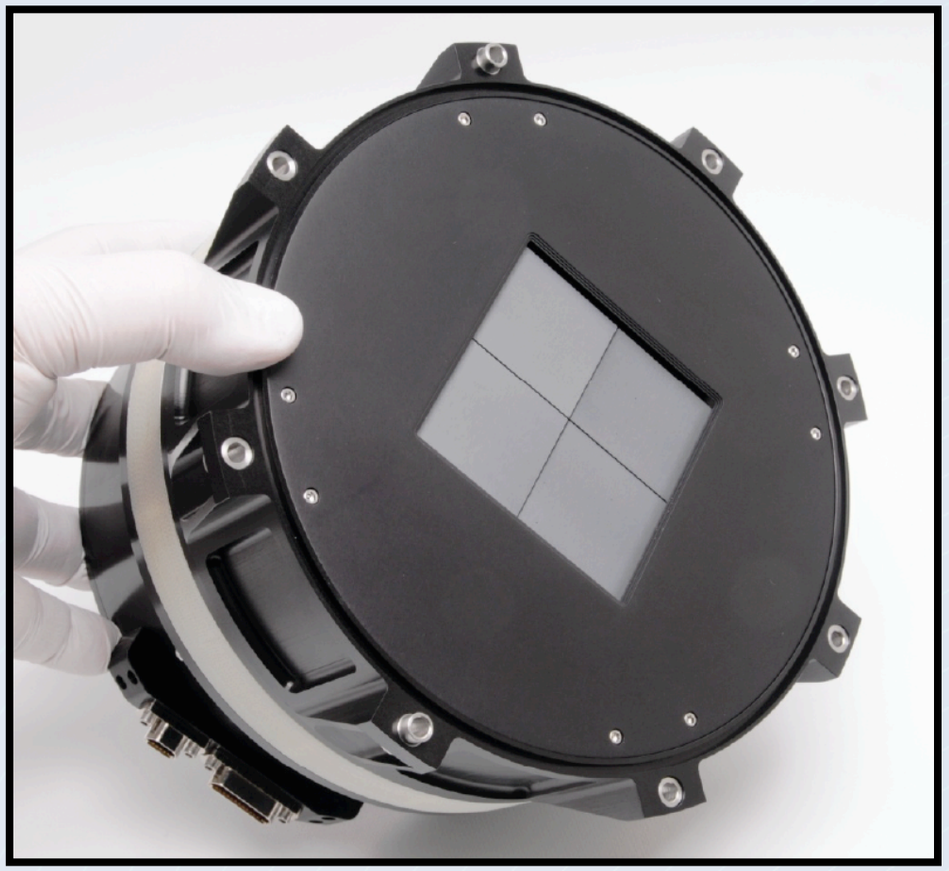
TESS Flight CCD Wafers (in progress at Lincoln Lab)



TESS Prototype Focal Plane Assembly



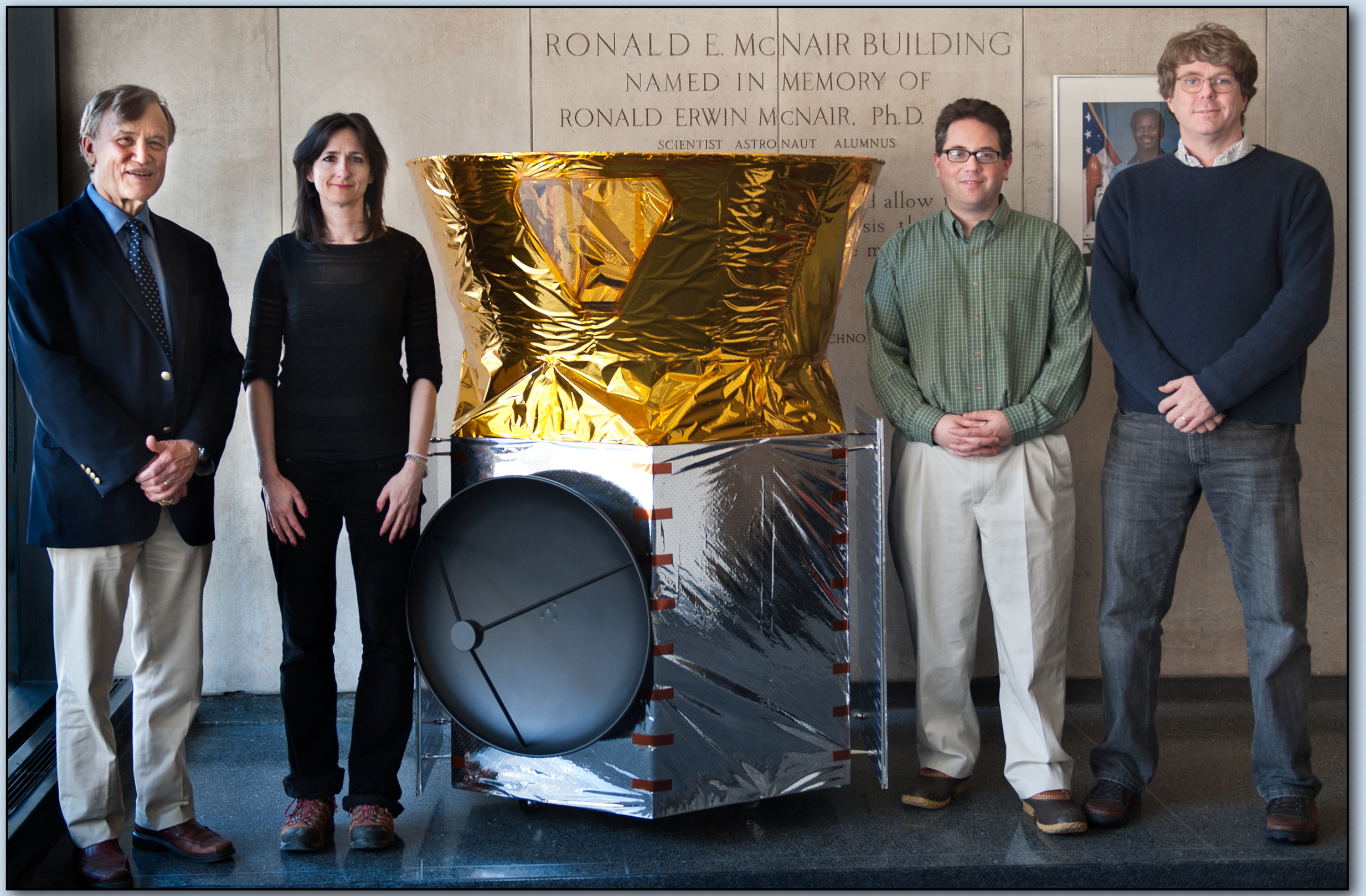
A) Array of 4 CCDs During Assembly



B) Completed CCD Focal Plane Array
(Frame Store Cover in Place)

TESS Wide FOV CCD Camera Prototype

Full Size Replica of TESS

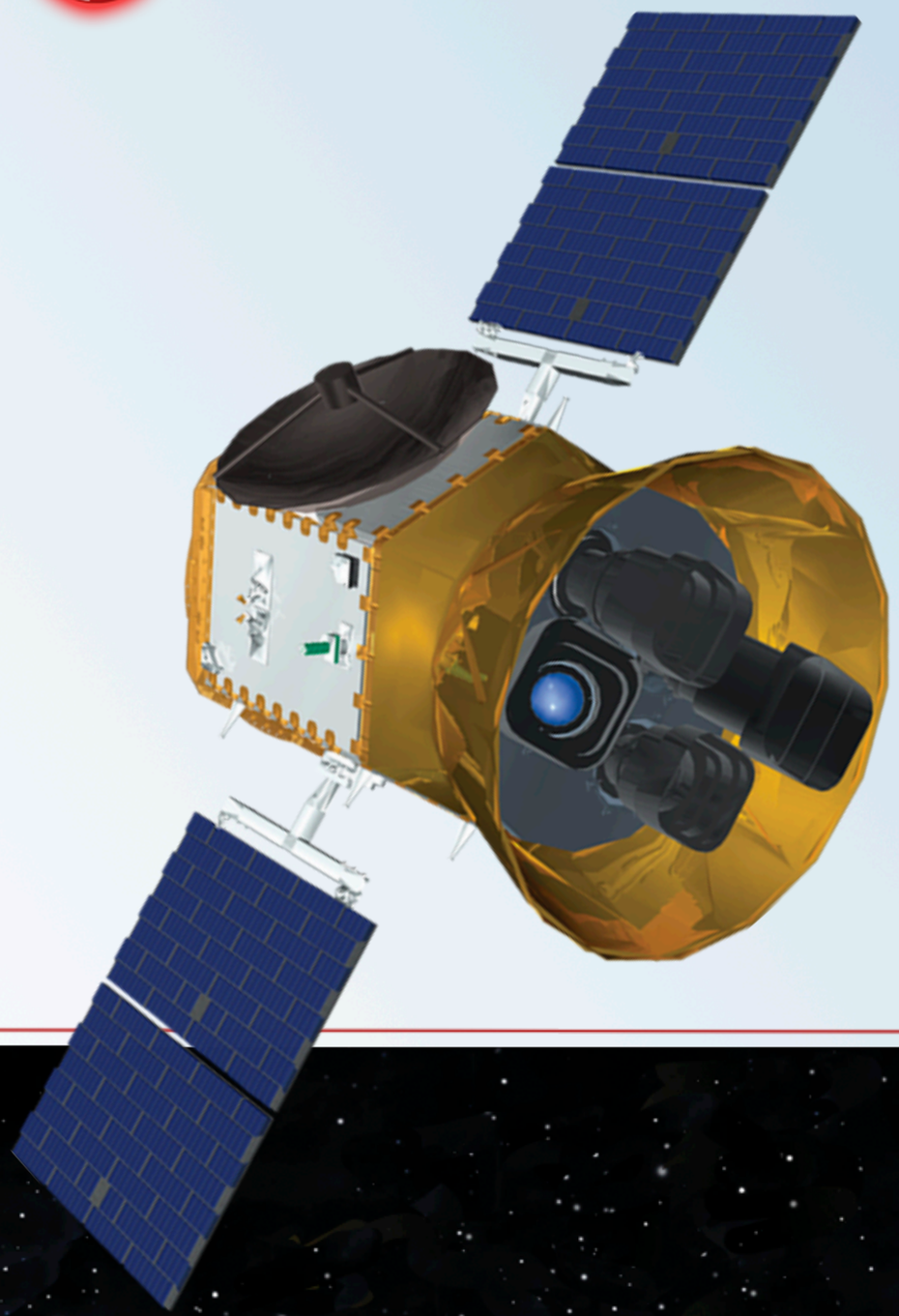


How TESS Gets Launch Ready By 2017…

- Simple Mission Design
  - *HEO assures stable instrument operation*
    - *Anti-sun, fixed inertial pointing*
    - *Infrequent maneuvers*
  - *All cooling is passive*
  - *Solar panels are the only deployable*

- Four Identical Cameras
  - *Modest aperture*
- Simple Payload Interface to Orbital's Heritage Bus
  - *Cameras bolt in place with no critical alignments*

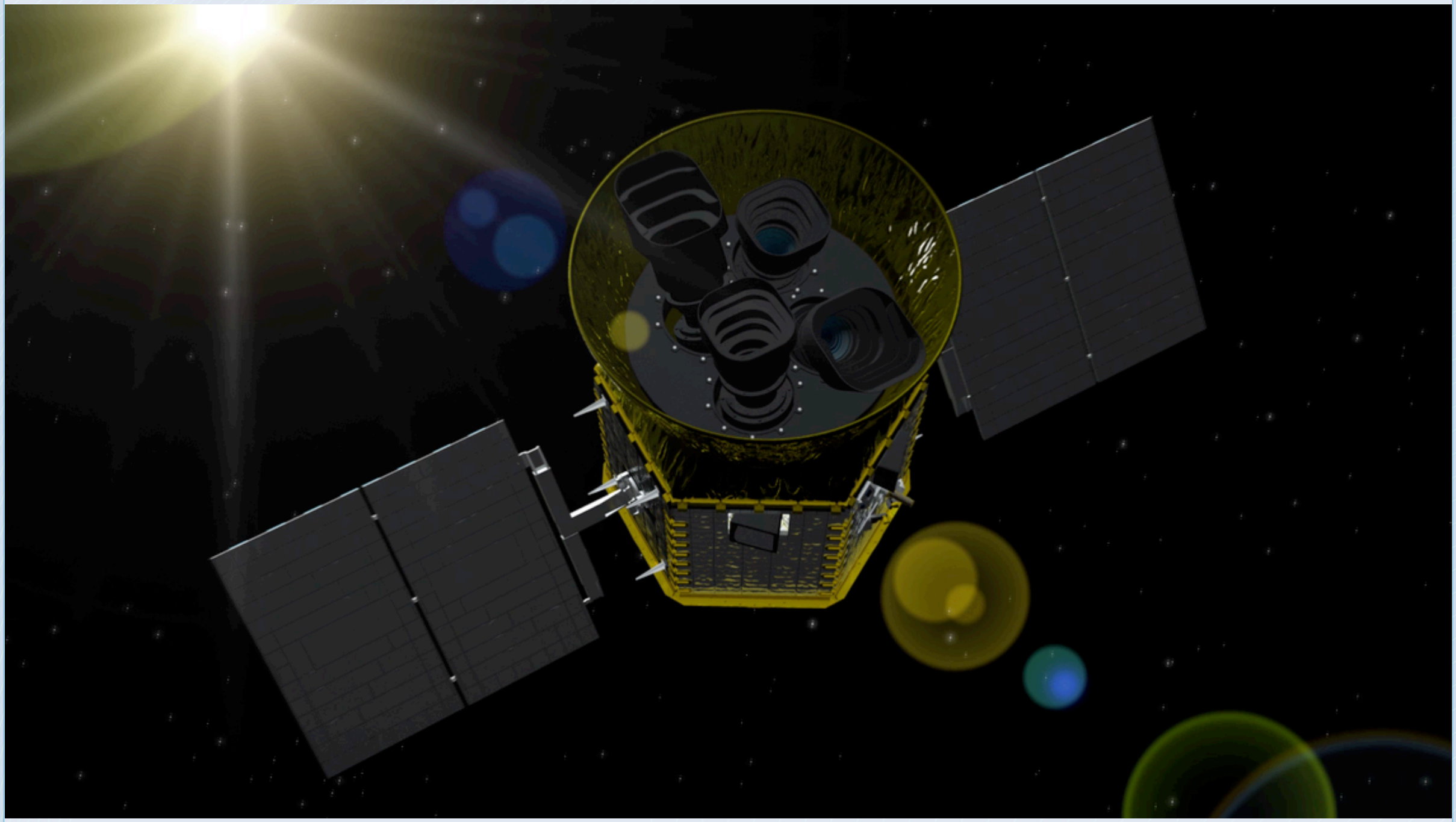
Transiting Exoplanet Survey Satellite



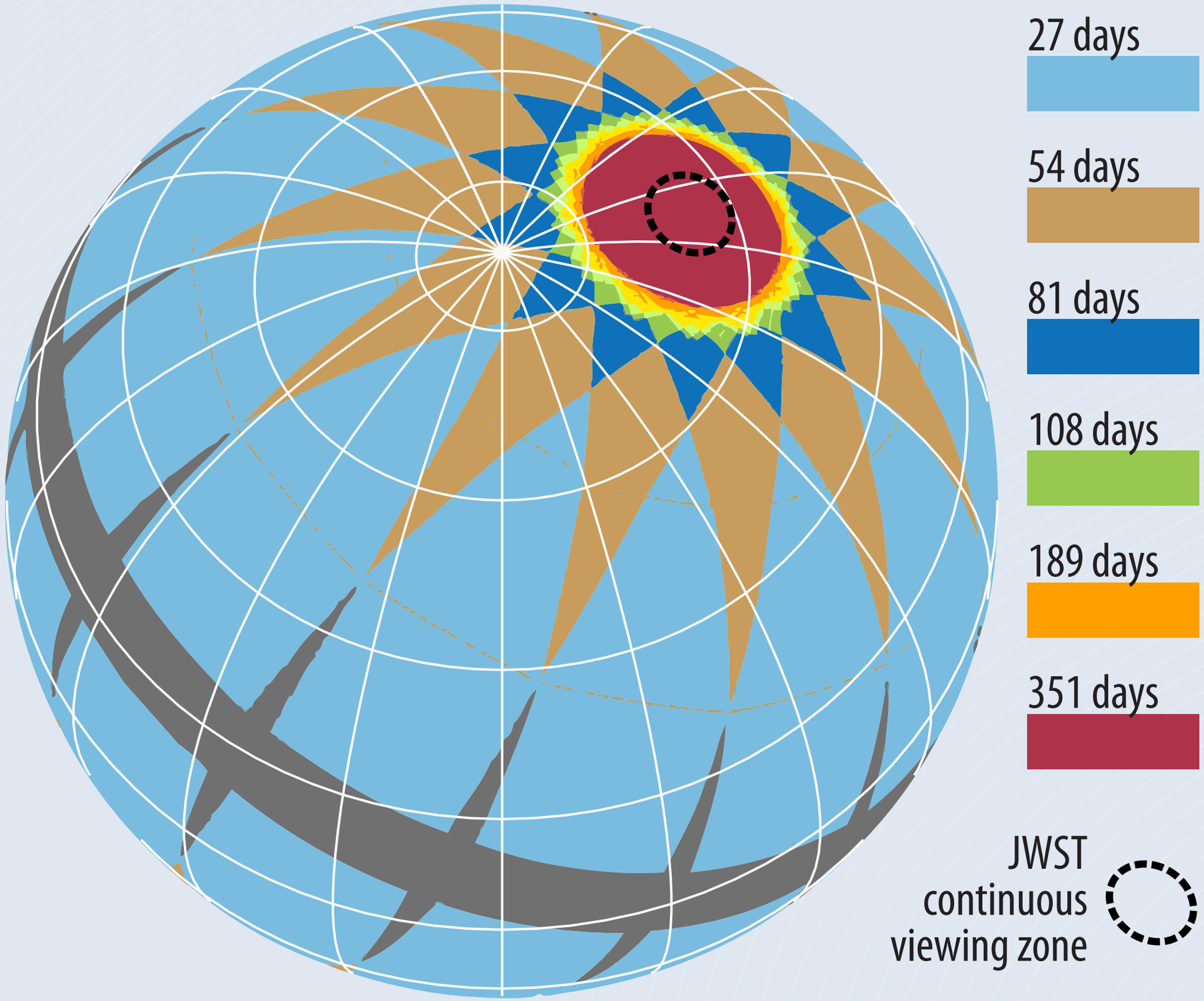
TESS Mission Videos

http://www.youtube.com/watch?v=mpViVEO-ymc

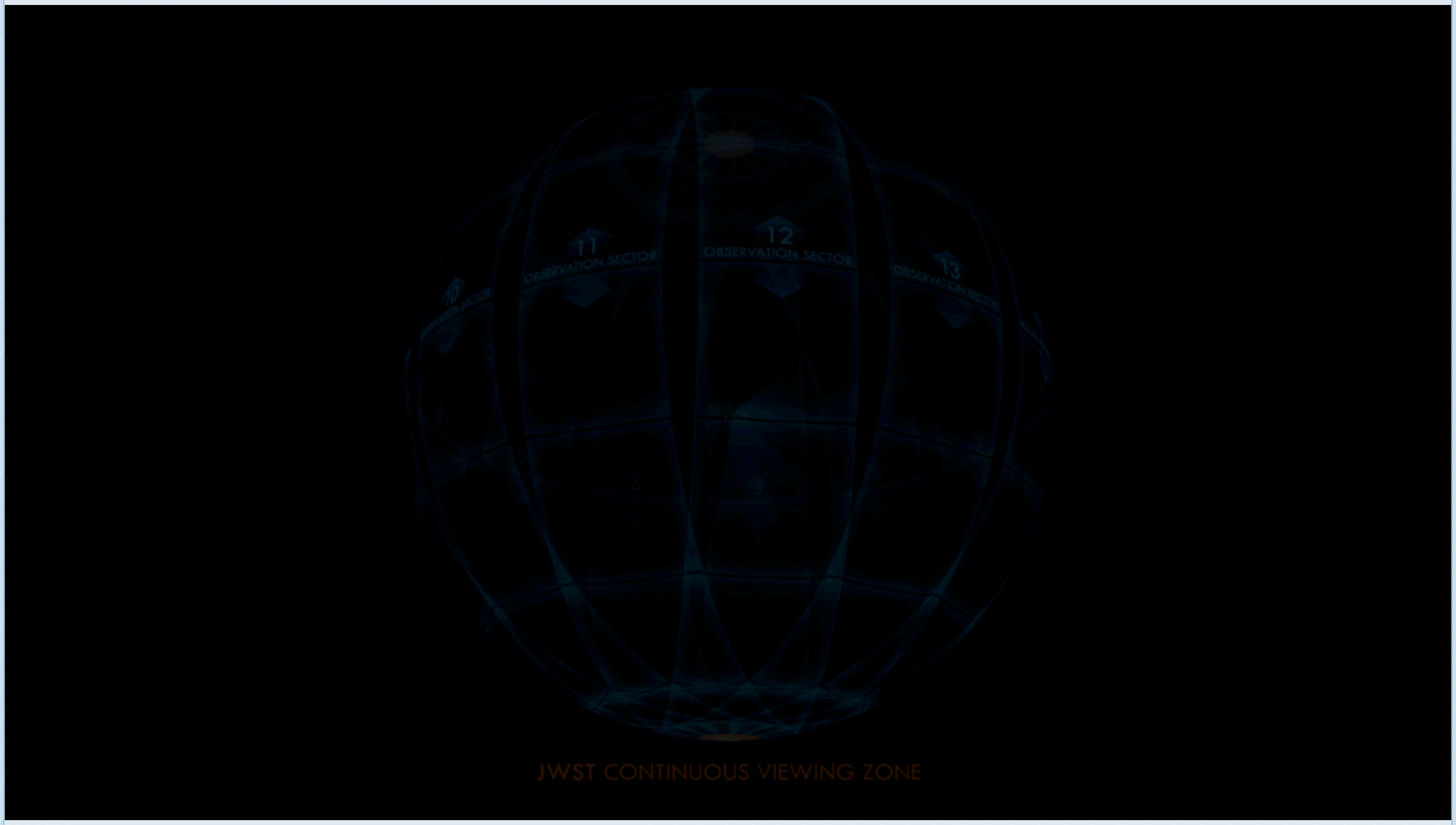
TESS Sky Mapping Strategy



TESS 2-year Sky Coverage Map



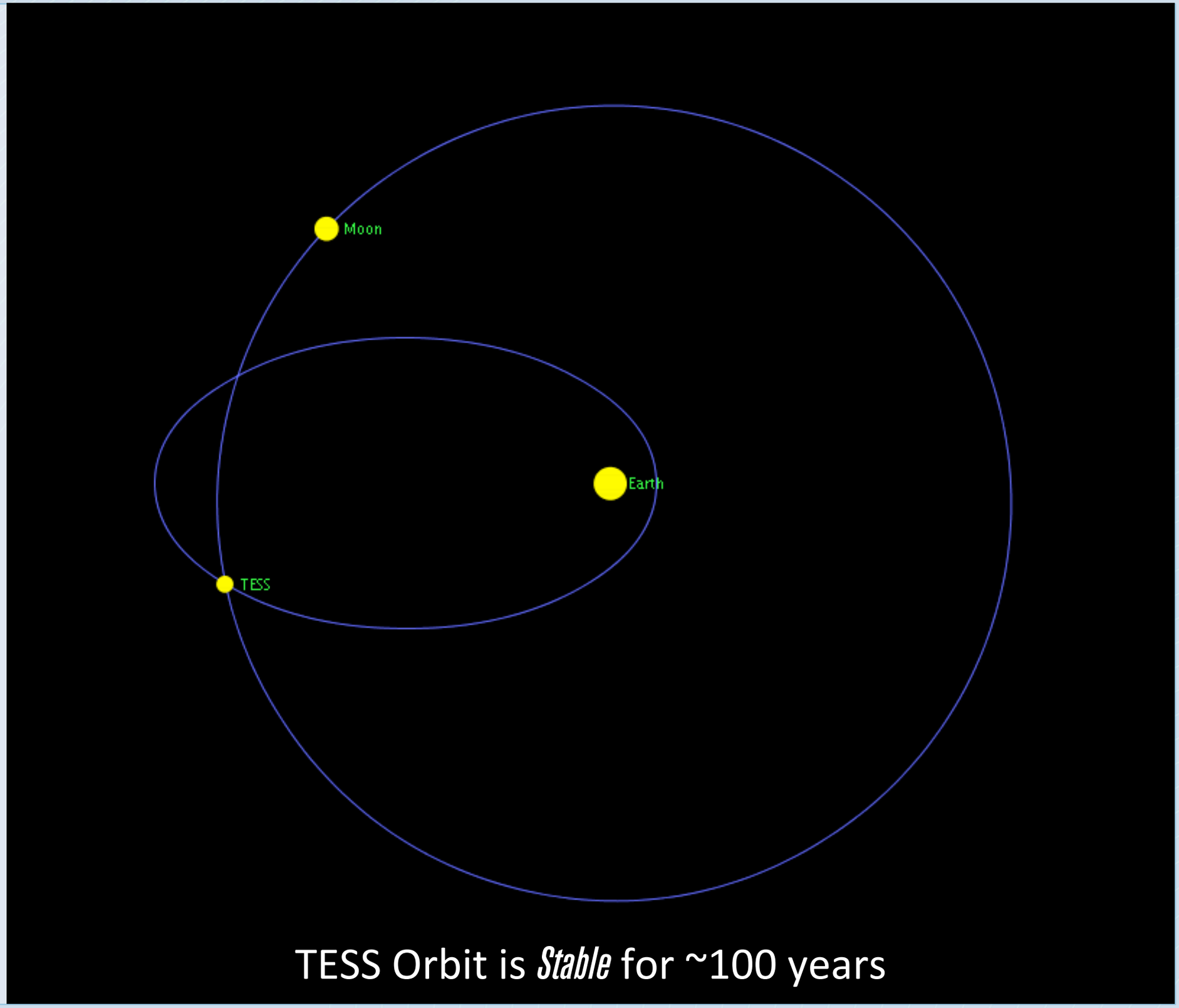
TESS Orbit Insertion



TESS's Novel High Orbit

Uninterrupted viewing for >95% of time

Orbital Periods:
TESS = 13.7 days
Moon = 27.4 days
➡ 2:1 Resonance
➡ 90° Phasing



TESS Orbit is *Stable* for ~100 years

"Special" Orbit Enables and Simplifies TESS

1) High Observing Efficiency: *>95%*

2) Thermal stability: *<50 mK/hr (passive control only)*

3) Earth/Moon Stray Light Tolerance: *10^{-6} (vs 10^{-12} in LEO)*

4) Low Radiation Levels: *No SAA, No Outer Belt Electrons*

5) Frequent Launch Windows: *23 of 27 days per lunar month*

6) **High Data Rates:** *100 Mbit/s (200 GB in 3hr at Perigee)*

[$1/R^2$ advantage: ~200x Earth-Sun L2; ~10,000x Kepler-type Orbit]

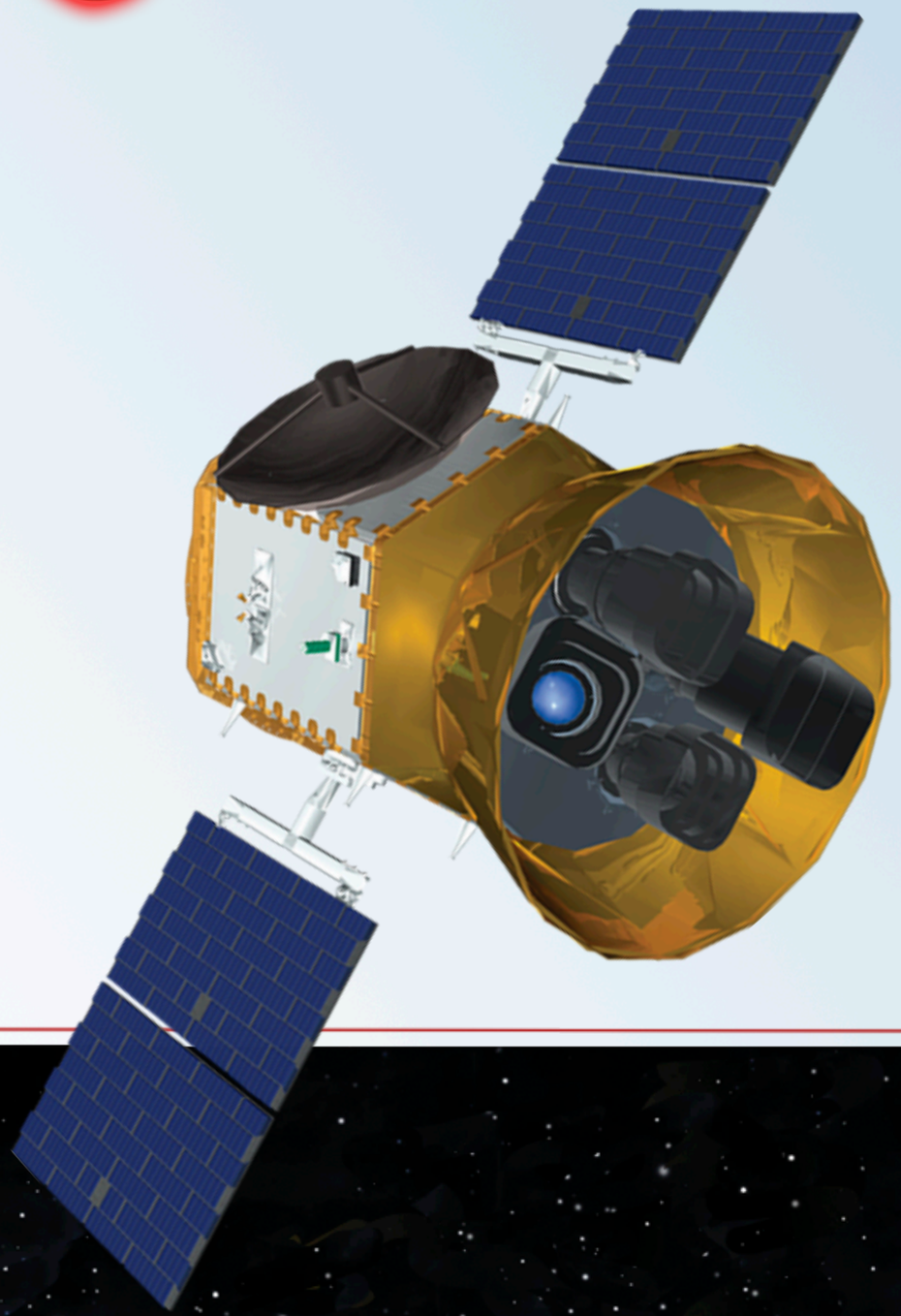
7) Excellent Pointing Stability: *No Drag, No Gravity Gradient*

8) Simple operations: *Single 4 hr Downlink & Repoint every 2 wks*

9) Long Orbit Lifetime: *~Several Decades (Perigee > 6.6 R_E)*

Gangestad et al. 2013 (astro-ph 1306.5333)

Transiting Exoplanet Survey Satellite

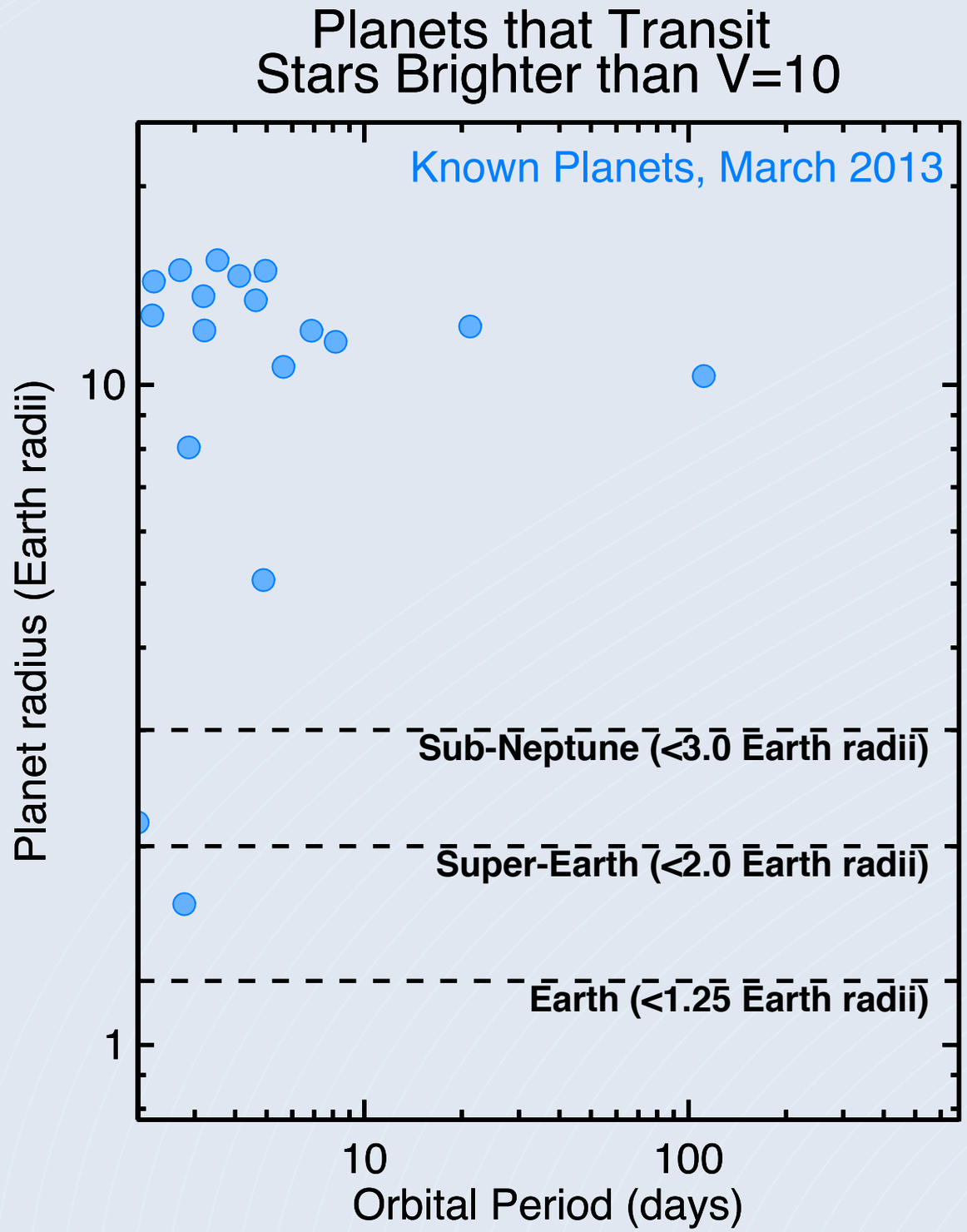


Why TESS?

Why Now?

Small Planets and Bright Stars

- ***Kepler:*** The most common members of the exoplanet family are Earths and Super-Earths
- Population of characterizable Earths and Super-Earths is extremely impoverished
- Two smallest transiting exoplanets with bright hosts were discovered from space:
  - *Kepler-21b: Kepler Team*
  - *55 Cnc e: MOST [Co-I Josh Winn]*



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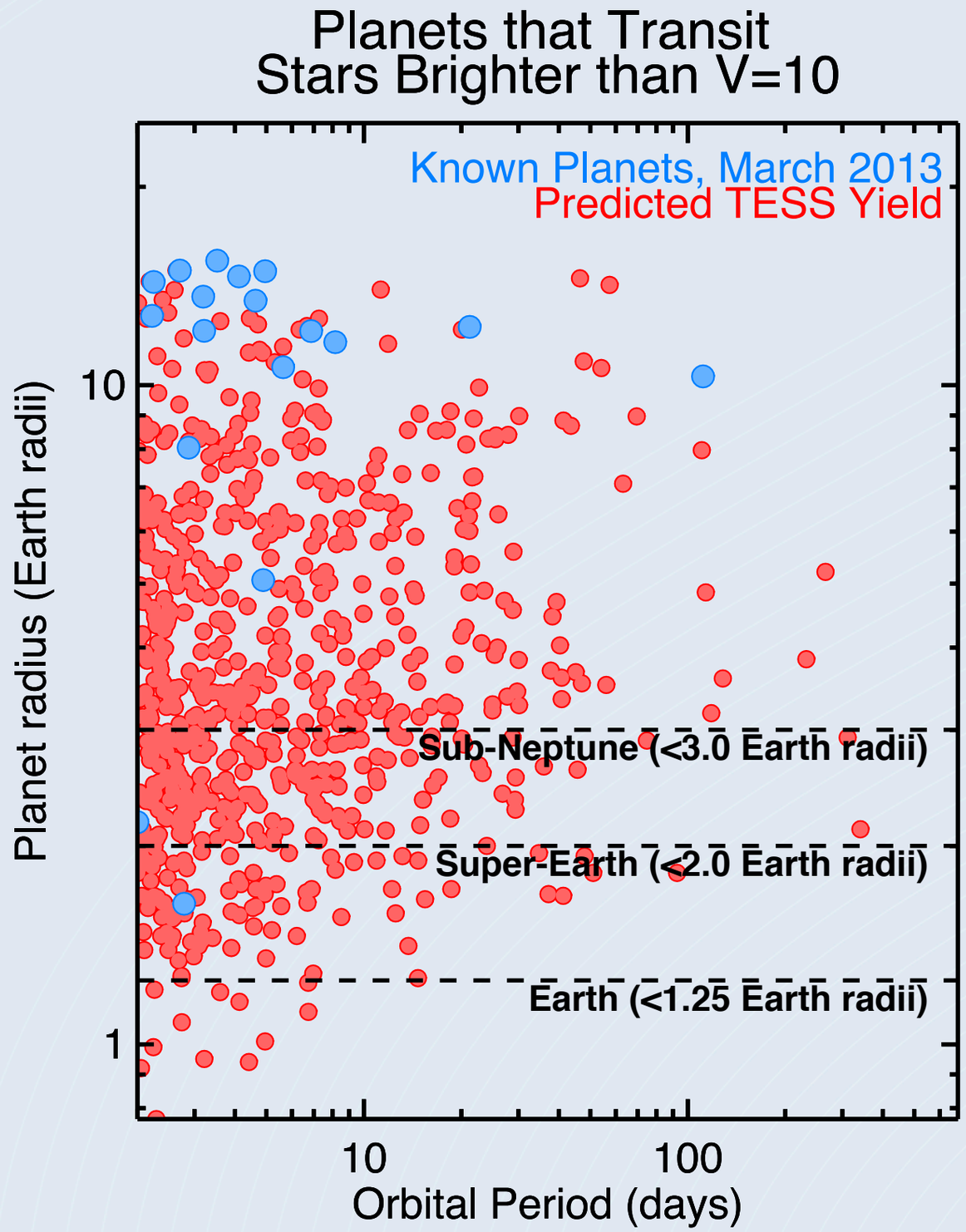
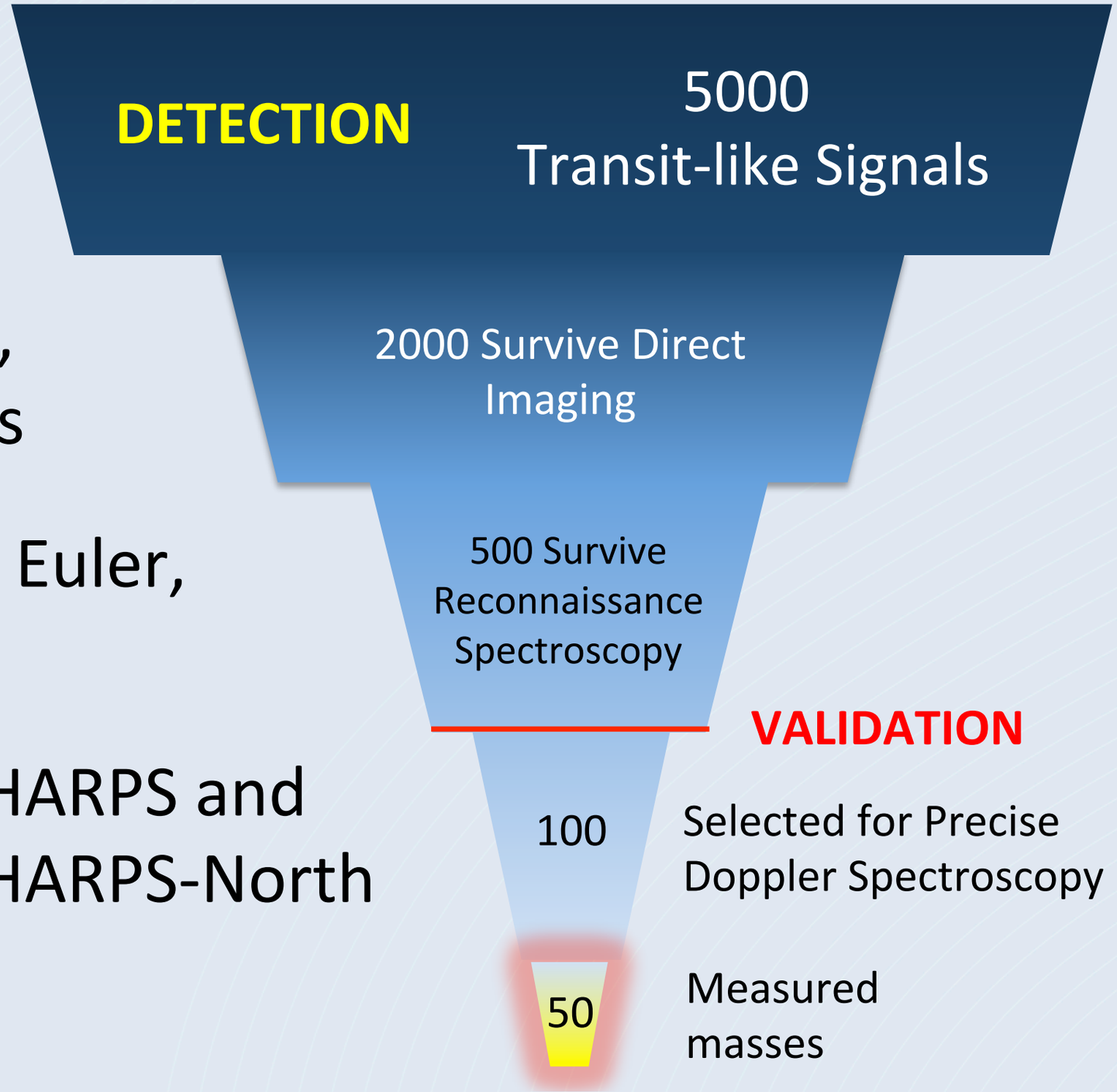
TESS Will Discover the Earths and Super-Earths Transiting the Brightest & Nearest Stars

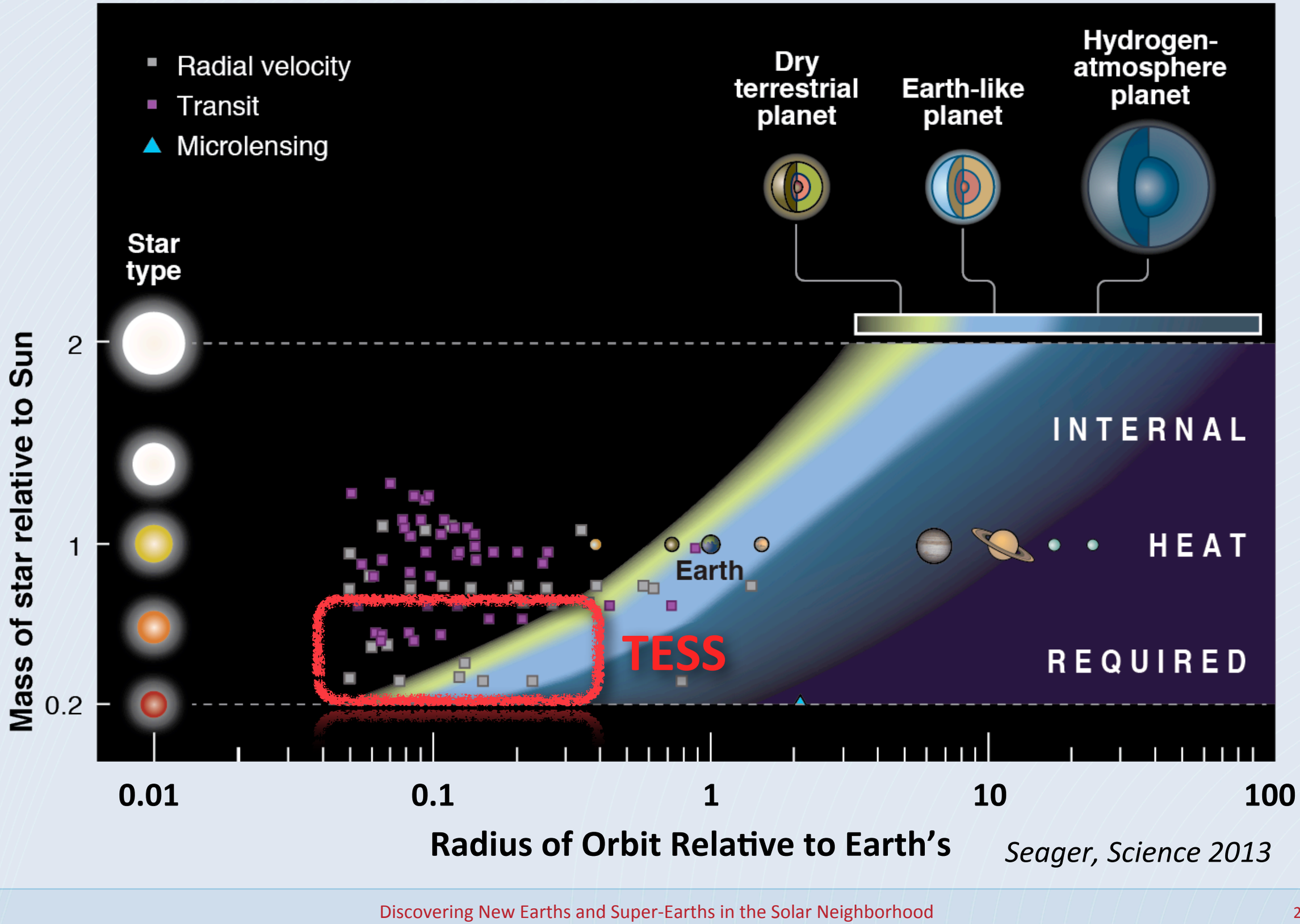


TESS Planet Validation and Mass Measurement

- TESS spacecraft data
  - LCOGT, MEarth, Euler telescopes
    - LCOGT, Euler, OHP
      - HARPS and HARPS-North



TESS and the Habitable Zone



Seager, Science 2013

TESS: A Bridge to the Future…